FIG. 1

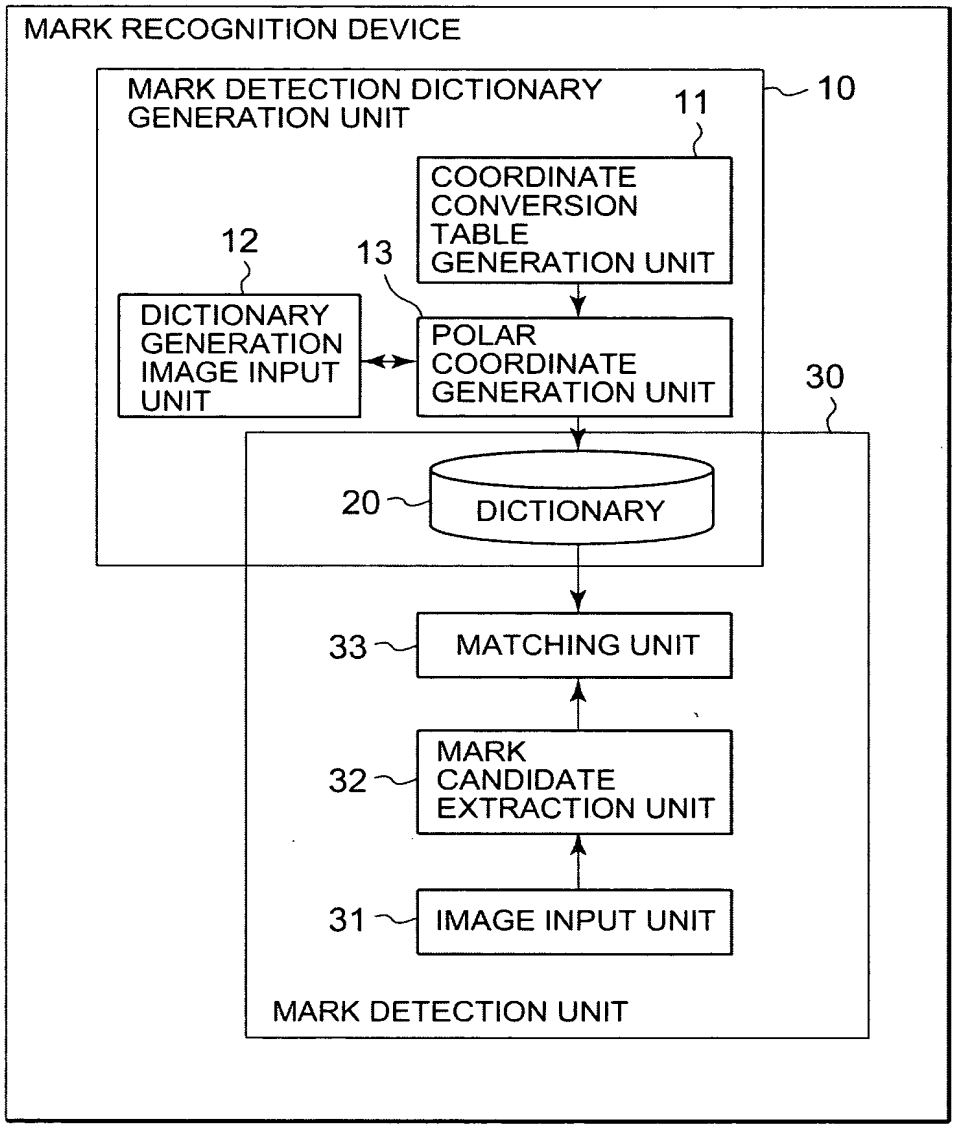

MARK RECOGNITION DEVICE
MARK DETECTION DICTIONARY GENERATION UNIT
10
11
COORDINATE CONVERSION TABLE GENERATION UNIT
12
13
DICTIONARY GENERATION IMAGE INPUT UNIT
POLAR COORDINATE GENERATION UNIT
30
20
DICTIONARY
33
MATCHING UNIT
32
MARK CANDIDATE EXTRACTION UNIT
31
IMAGE INPUT UNIT
MARK DETECTION UNIT

Fig. 2A

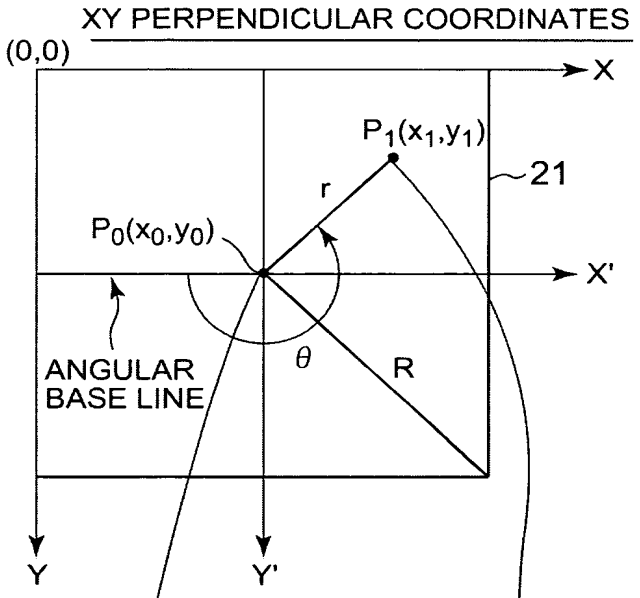

XY PERPENDICULAR COORDINATES
(0,0)
X
$P_1(x_1,y_1)$
21
r
$P_0(x_0,y_0)$
X'
ANGULAR
BASE LINE
θ
R
Y
Y'

Fig. 2B

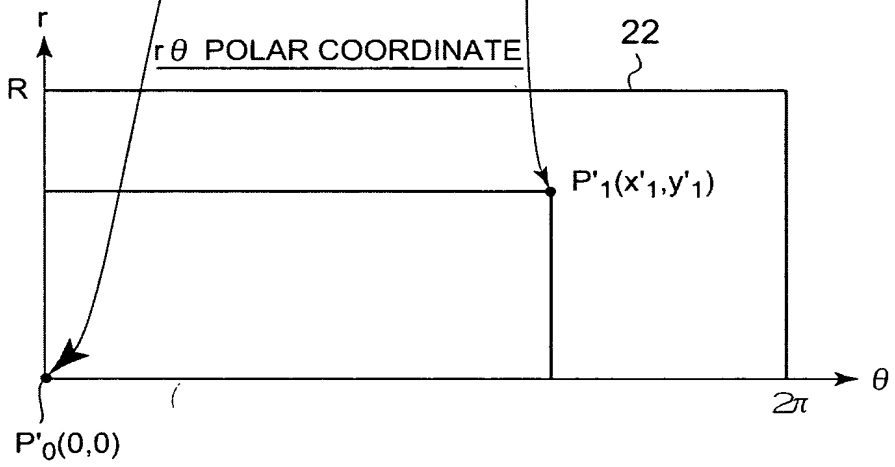

r
rθ POLAR COORDINATE
22
R
$P'_1(x'_1,y'_1)$
θ
2π
$P'_0(0,0)$

Fig. 3

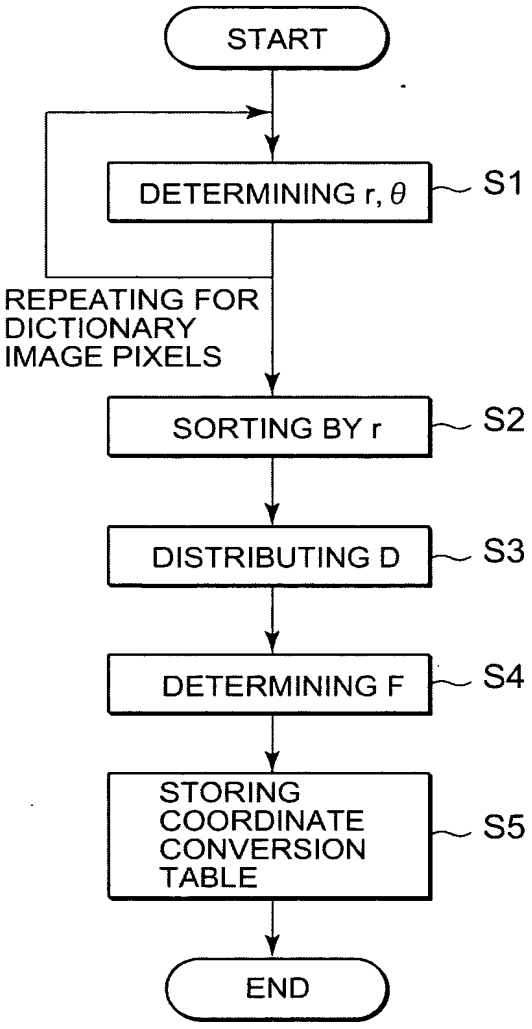

START
DETERMINING r, θ
S1
REPEATING FOR DICTIONARY IMAGE PIXELS
SORTING BY r
S2
DISTRIBUTING D
S3
DETERMINING F
S4
STORING COORDINATE CONVERSION TABLE
S5
END

Fig. 4

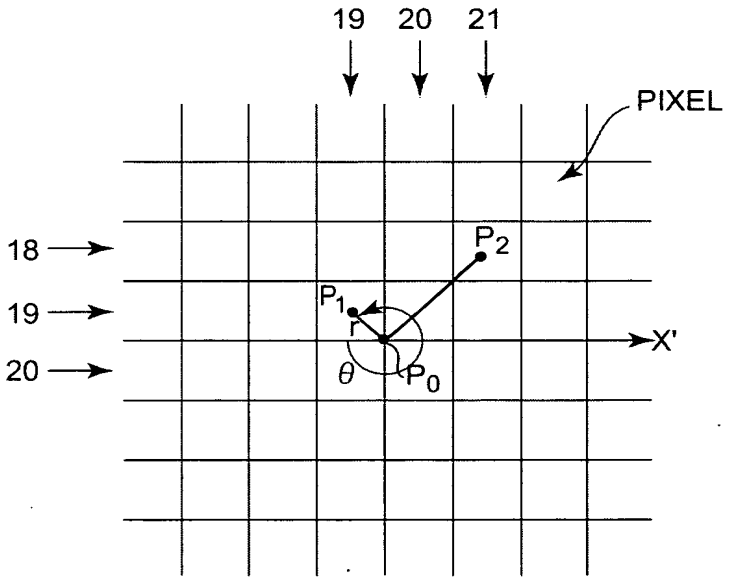


Fig. 5

No.	X	Y	r	θ
0	19	20	0.71	0.785398
1	20	20	0.71	2.356194
2	20	19	0.71	3.926991
3	19	19	0.71	5.497787
4	18	20	1.58	0.321751
5	19	21	1.58	1.249046
6	20	21	1.58	1.892547
7	21	20	1.58	2.819842
8	21	19	1.58	3.463343
9	20	18	1.58	4.390638
10	19	18	1.58	5.034140
11	18	19	1.58	5.961435
12	18	21	2.12	0.785398
13	21	21	2.12	2.356194
14	21	18	2.12	3.926991
15	18	18	2.12	5.497787
⋮	⋮	⋮	⋮	⋮

Fig. 6

No.	X	Y	D	r	θ
0	19	20	0	0.71	0.785398
1	20	20	0	0.71	2.356194
2	20	19	0	0.71	3.926991
3	19	19	0	0.71	5.497787
4	18	20	1	1.58	0.321751
5	19	21	1	1.58	1.249046
6	20	21	1	1.58	1.892547
7	21	20	1	1.58	2.819842
8	21	19	1	1.58	3.463343
9	20	18	1	1.58	4.390638
10	19	18	1	1.58	5.034140
11	18	19	1	1.58	5.961435
12	18	21	2	2.12	0.785398
13	21	21	2	2.12	2.356194
14	21	18	2	2.12	3.926991
15	18	18	2	2.12	5.497787
⋮	⋮	⋮	⋮	⋮	⋮

Fig. 7

No.	X	Y	D	r	F	θ
0	19	20	0	0.71	24	0.785398
1	20	20	0	0.71	72	2.356194
2	20	19	0	0.71	120	3.926991
3	19	19	0	0.71	168	5.497787
4	18	20	1	1.58	10	0.321751
5	19	21	1	1.58	38	1.249046
6	20	21	1	1.58	58	1.892547
7	21	20	1	1.58	86	2.819842
8	21	19	1	1.58	106	3.463343
9	20	18	1	1.58	134	4.390638
10	19	18	1	1.58	154	5.034140
11	18	19	1	1.58	182	5.961435
12	18	21	2	2.12	24	0.785398
13	21	21	2	2.12	72	2.356194
14	21	18	2	2.12	120	3.926991
15	18	18	2	2.12	168	5.497787
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Fig. 8A

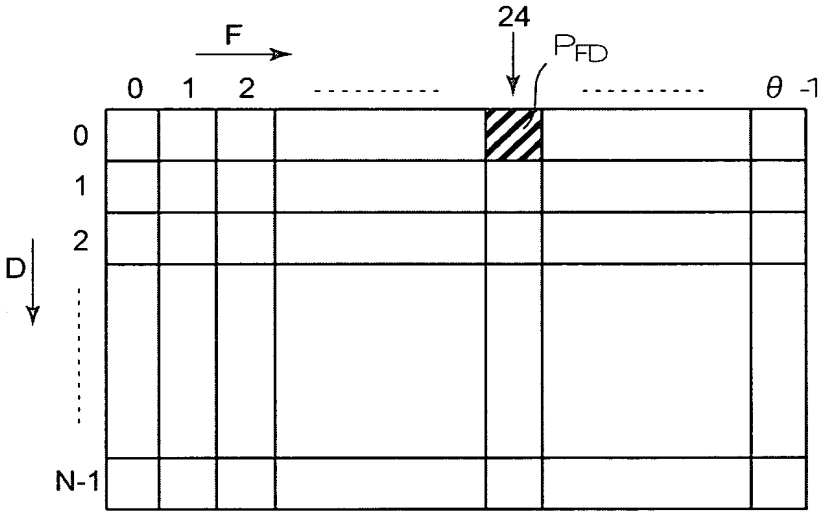


Fig. 8B

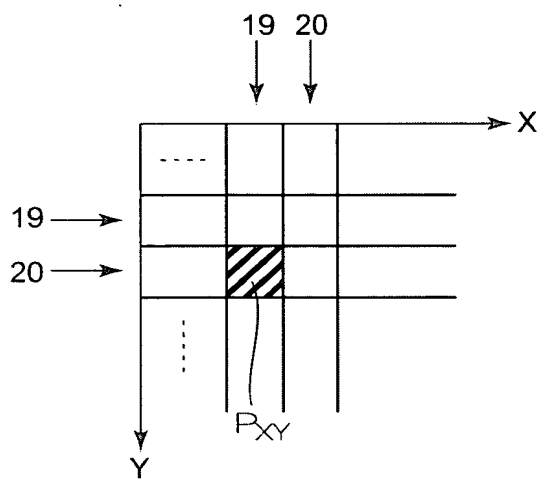


Fig. 9

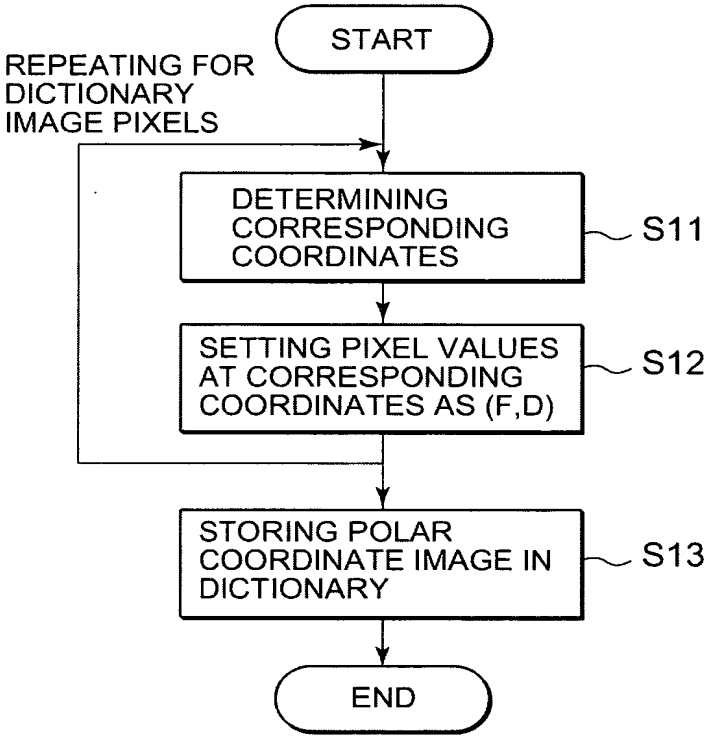

START
REPEATING FOR DICTIONARY IMAGE PIXELS
DETERMINING CORRESPONDING COORDINATES
S11
SETTING PIXEL VALUES AT CORRESPONDING COORDINATES AS (F,D)
S12
STORING POLAR COORDINATE IMAGE IN DICTIONARY
S13
END

Fig. 10

X
Y
RC
OH

Fig. 11

Fig. 12

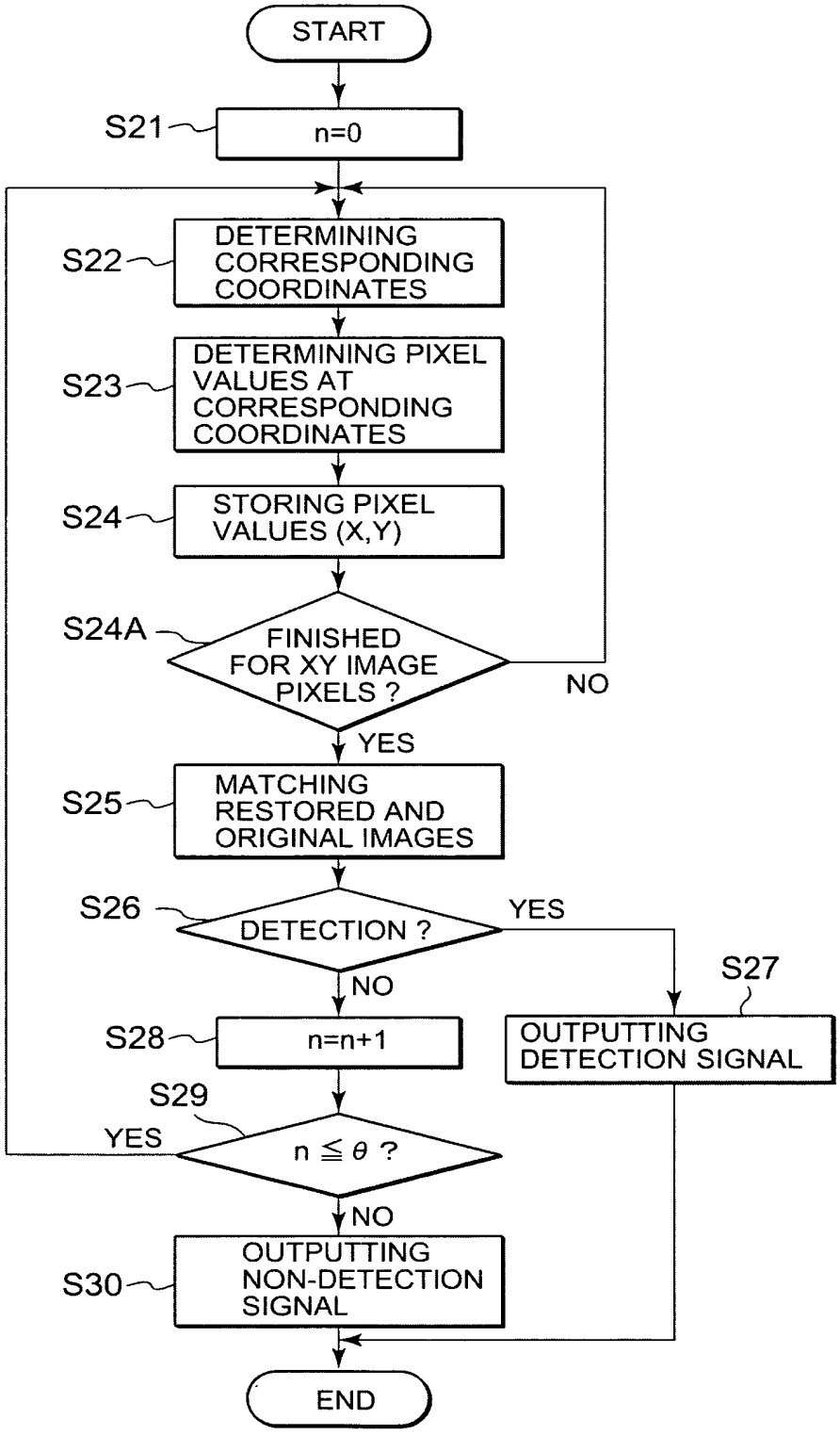

START
S21
n=0
S22
DETERMINING CORRESPONDING COORDINATES
S23
DETERMINING PIXEL VALUES AT CORRESPONDING COORDINATES
S24
STORING PIXEL VALUES (X,Y)
S24A
FINISHED FOR XY IMAGE PIXELS ?
NO
YES
S25
MATCHING RESTORED AND ORIGINAL IMAGES
S26
DETECTION ?
YES
NO
S27
OUTPUTTING DETECTION SIGNAL
S28
n=n+1
S29
n ≦ θ ?
YES
NO
S30
OUTPUTTING NON-DETECTION SIGNAL
END

Fig. 13

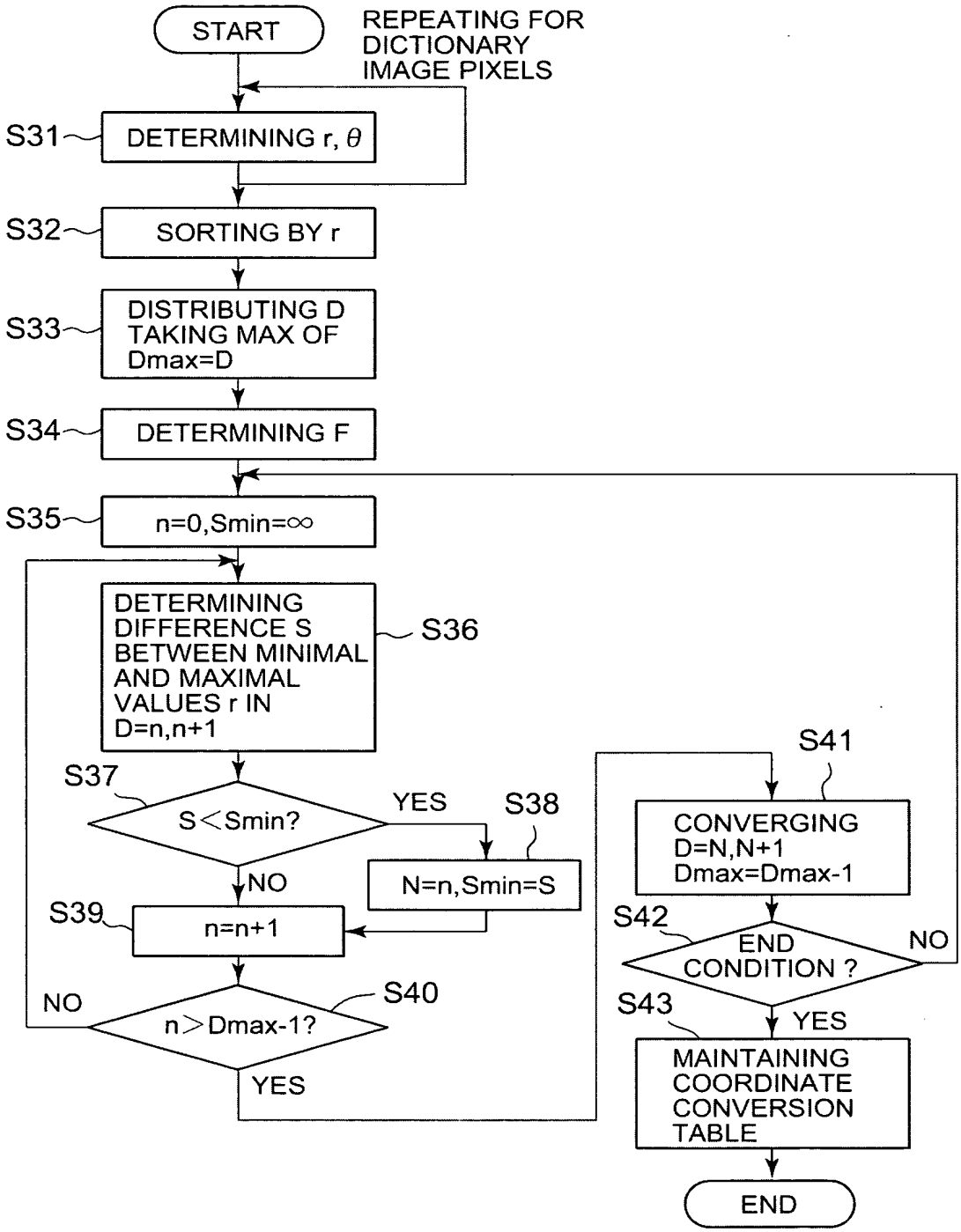

START
REPEATING FOR DICTIONARY IMAGE PIXELS
S31
DETERMINING r, θ
S32
SORTING BY r
S33
DISTRIBUTING D TAKING MAX OF Dmax=D
S34
DETERMINING F
S35
n=0,Smin=∞
DETERMINING DIFFERENCE S BETWEEN MINIMAL AND MAXIMAL VALUES r IN D=n,n+1
S36
S37
S<Smin?
YES
S38
N=n,Smin=S
NO
S39
n=n+1
NO
n>Dmax-1?
S40
YES
S41
CONVERGING D=N,N+1 Dmax=Dmax-1
S42
END CONDITION ?
NO
S43
YES
MAINTAINING COORDINATE CONVERSION TABLE
END

Fig. 14

No.	X	Y	D	r	F	θ
0	19	20	0	0.71	24	0.785398
1	20	20	0	0.71	72	2.356194
2	20	19	0	0.71	120	3.926991
3	19	19	0	0.71	168	5.497787
4	18	20	0	1.58	10	0.321751
5	19	21	0	1.58	38	1.249046
6	20	21	0	1.58	58	1.892547
7	21	20	0	1.58	86	2.819842
8	21	19	0	1.58	106	3.463343
9	20	18	0	1.58	134	4.390638
10	19	18	0	1.58	154	5.034140
11	18	19	0	1.58	182	5.961435
12	18	21	1	2.12	24	0.785398
13	21	21	1	2.12	72	2.356194
14	21	18	1	2.12	120	3.926991
15	18	18	1	2.12	168	5.497787
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Fig. 15

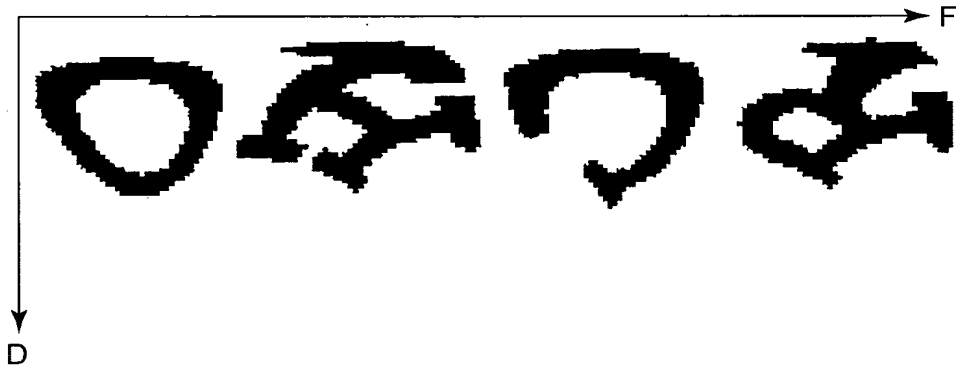


Fig. 16

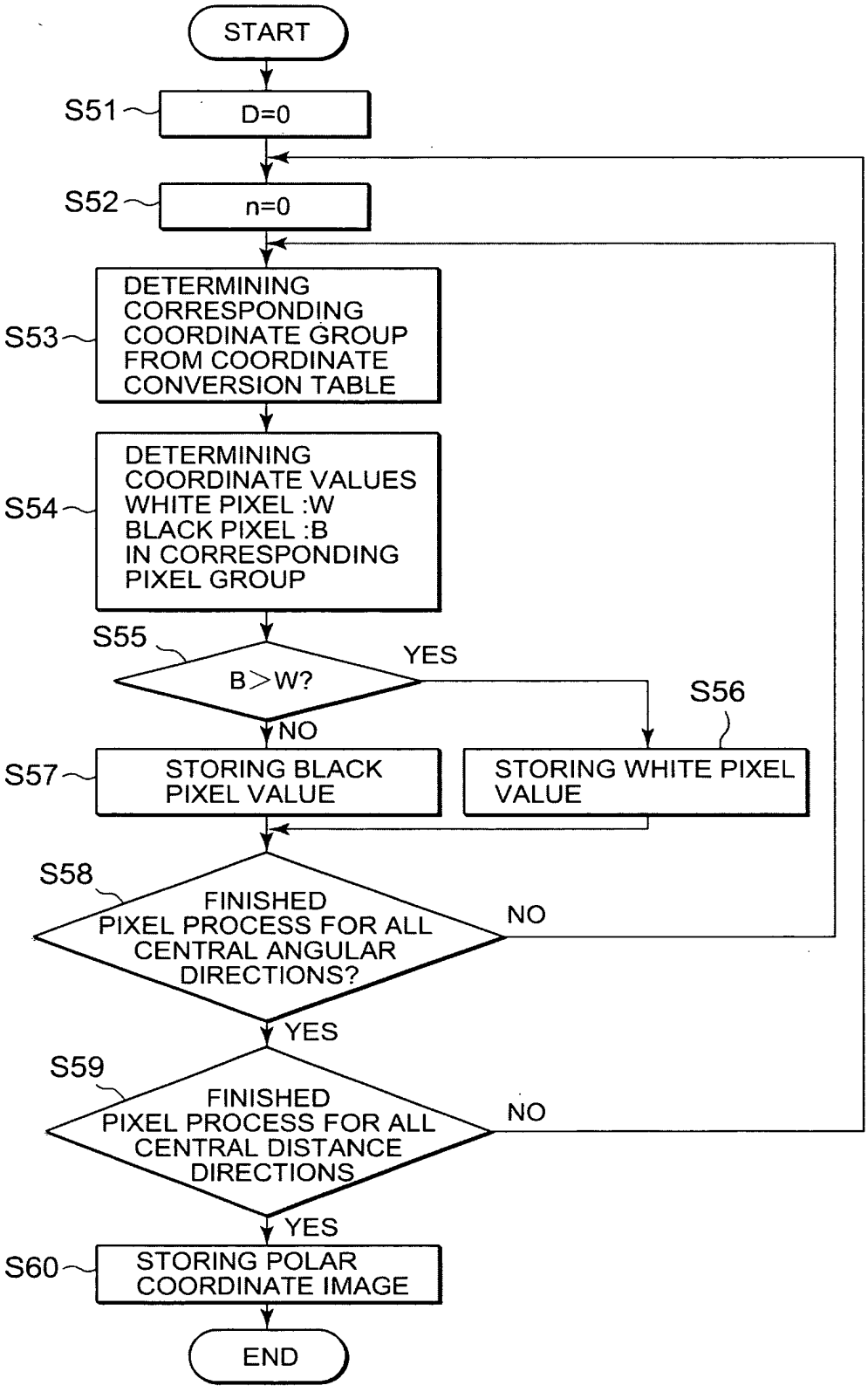
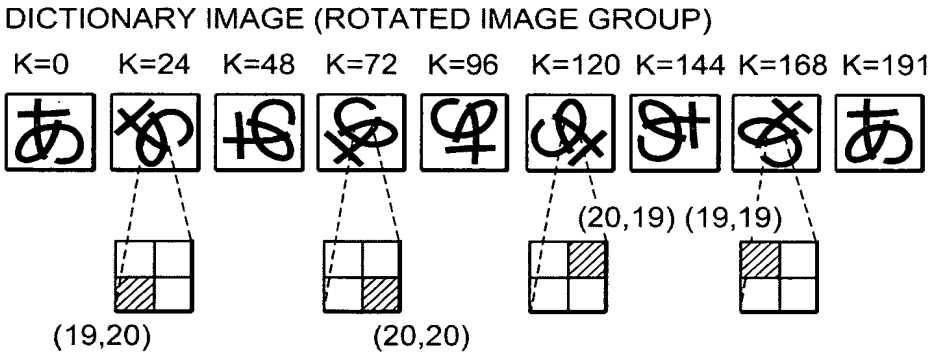

START
S51
D=0
S52
n=0
S53
DETERMINING CORRESPONDING COORDINATE GROUP FROM COORDINATE CONVERSION TABLE
S54
DETERMINING COORDINATE VALUES WHITE PIXEL :W BLACK PIXEL :B IN CORRESPONDING PIXEL GROUP
S55
B>W?
YES
S56
NO
S57
STORING BLACK PIXEL VALUE
STORING WHITE PIXEL VALUE
S58
FINISHED PIXEL PROCESS FOR ALL CENTRAL ANGULAR DIRECTIONS?
NO
YES
S59
FINISHED PIXEL PROCESS FOR ALL CENTRAL DISTANCE DIRECTIONS
NO
YES
S60
STORING POLAR COORDINATE IMAGE
END

Fig. 17

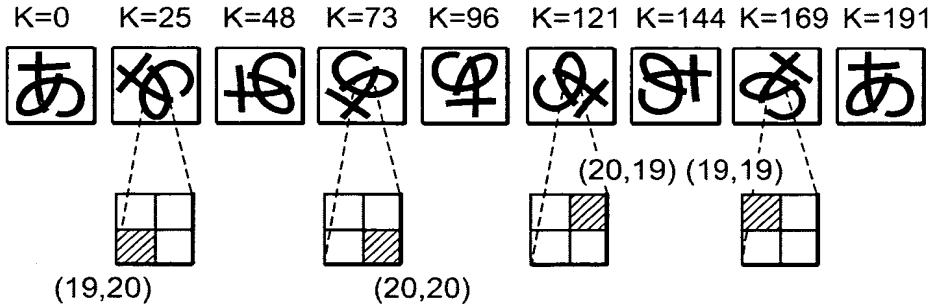


XY COORDINATE→ r θ COORDINATE CONVERSION TABLE

No.	X	Y	D	F
0	19	20	0	24
1	20	20	0	72
2	20	19	0	120
3	19	19	0	168

FROM FOUR ▨ PIXELS, PIXEL VALUES AT (F,D)=(0,0) IN POLAR COORDINATE IMAGE ARE DETERMINED.

Fig. 18



XY COORDINATE→ r θ COORDINATE CONVERSION TABLE

No.	X	Y	D	F
0	19	20	0	24
1	20	20	0	72
2	20	19	0	120
3	19	19	0	168

FROM FOUR ▨ PIXELS, PIXEL VALUES AT (F,D)=(0,0) IN POLAR COORDINATE IMAGE ARE DETERMINED.

Fig. 19

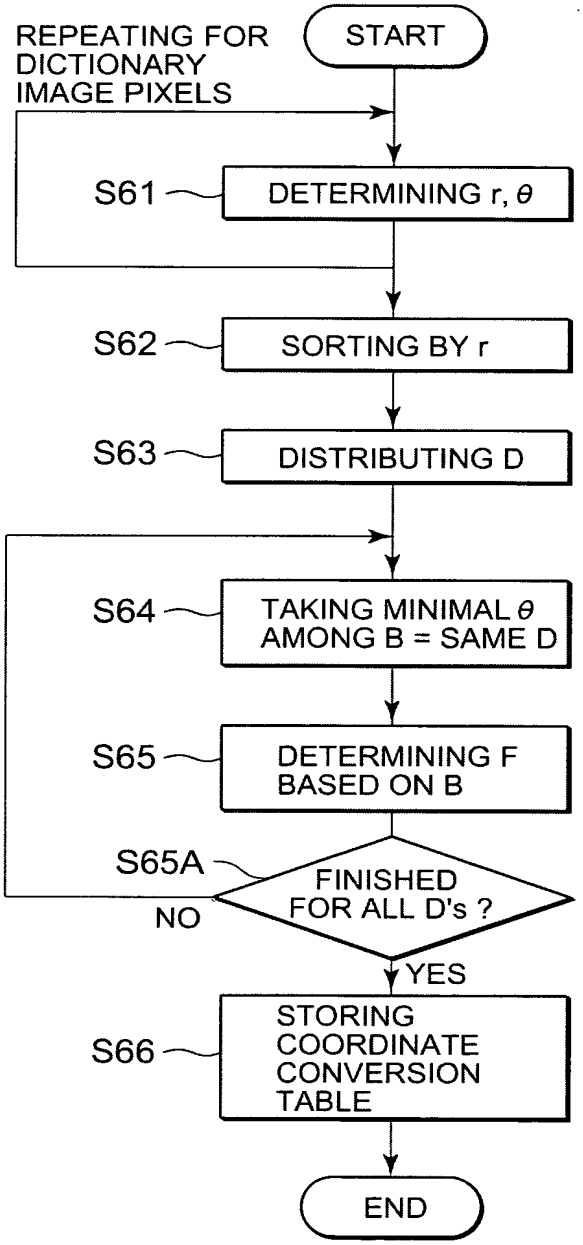

REPEATING FOR DICTIONARY IMAGE PIXELS
START
S61
DETERMINING r, θ
S62
SORTING BY r
S63
DISTRIBUTING D
S64
TAKING MINIMAL θ AMONG B = SAME D
S65
DETERMINING F BASED ON B
S65A
FINISHED FOR ALL D's ?
NO
YES
S66
STORING COORDINATE CONVERSION TABLE
END

Fig. 20

No.	X	Y	D	r	F	θ
0	19	20	0	0.71	4	0.785398
1	20	20	0	0.71	48	2.356194
2	20	19	0	0.71	96	3.926991
3	19	19	0	0.71	144	5.497787
4	18	20	1	1.58	0	0.321751
5	19	21	1	1.58	28	1.249046
6	20	21	1	1.58	48	1.892547
7	21	20	1	1.58	76	2.819842
8	21	19	1	1.58	96	3.463343
9	20	18	1	1.58	124	4.390638
10	19	18	1	1.58	144	5.034140
11	18	19	1	1.58	172	5.961435
12	18	21	2	2.12	0	0.785398
13	21	21	2	2.12	48	2.356194
14	21	18	2	2.12	96	3.926991
15	18	18	2	2.12	144	5.497787
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Fig. 21

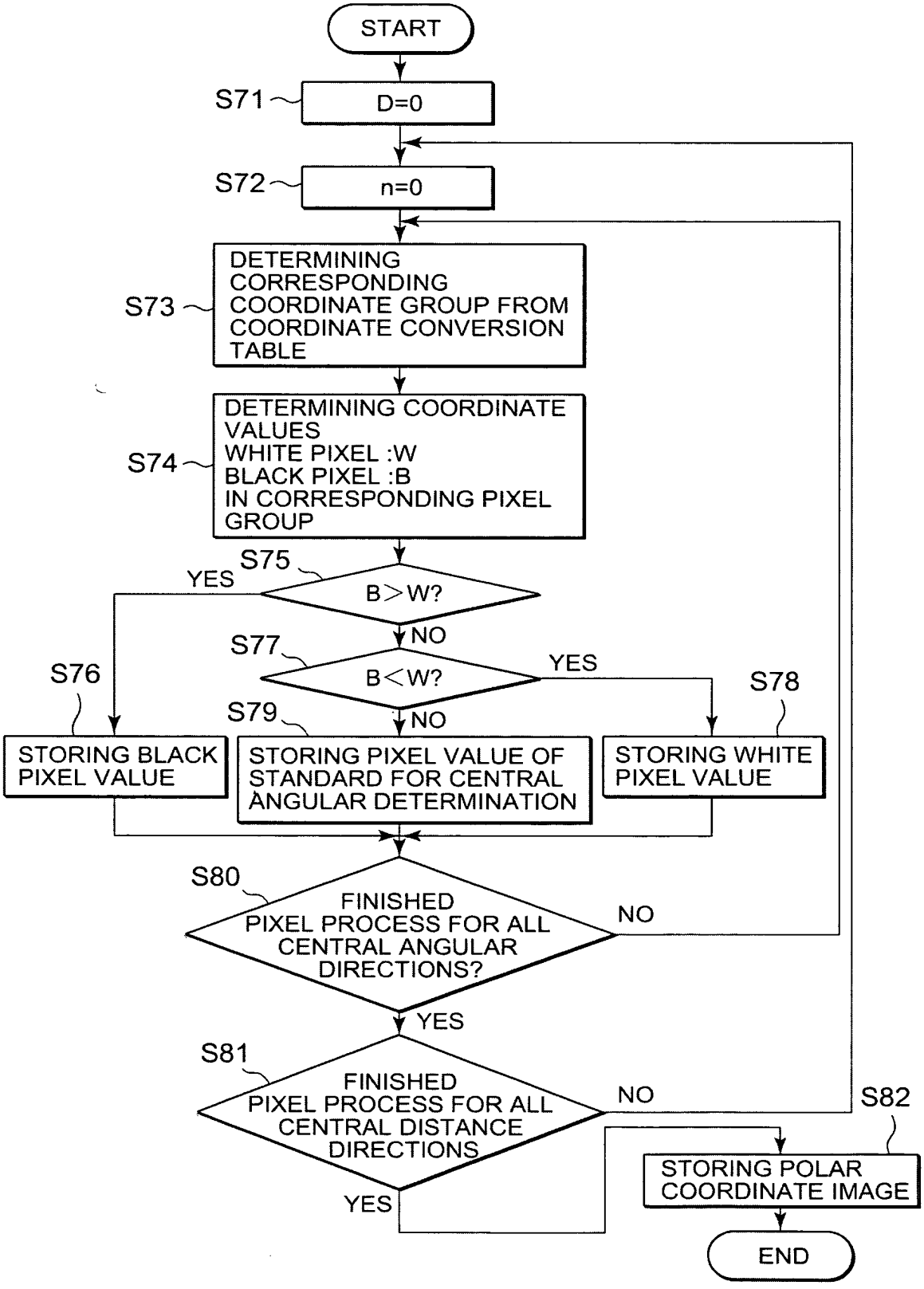
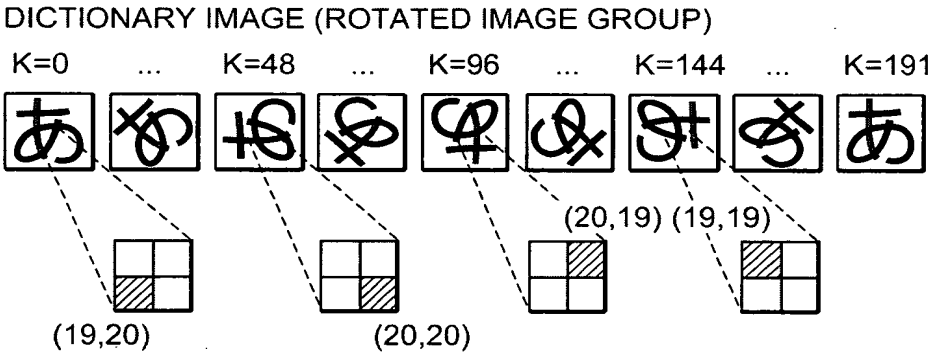

START
S71
D=0
S72
n=0
S73
DETERMINING CORRESPONDING COORDINATE GROUP FROM COORDINATE CONVERSION TABLE
S74
DETERMINING COORDINATE VALUES
WHITE PIXEL :W
BLACK PIXEL :B
IN CORRESPONDING PIXEL GROUP
S75
B>W?
YES
NO
S77
B<W?
YES
NO
S76
S78
S79
STORING BLACK PIXEL VALUE
STORING PIXEL VALUE OF STANDARD FOR CENTRAL ANGULAR DETERMINATION
STORING WHITE PIXEL VALUE
S80
FINISHED PIXEL PROCESS FOR ALL CENTRAL ANGULAR DIRECTIONS?
NO
YES
S81
FINISHED PIXEL PROCESS FOR ALL CENTRAL DISTANCE DIRECTIONS
NO
YES
S82
STORING POLAR COORDINATE IMAGE
END

Fig. 22

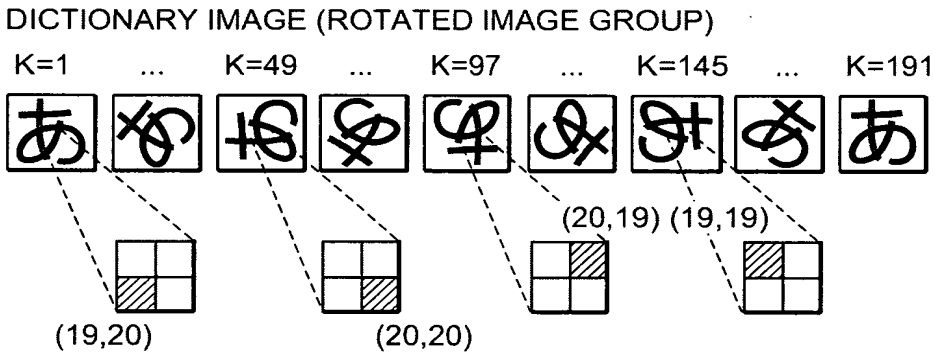


XY COORDINATE→ r θ COORDINATE CONVERSION TABLE

No.	X	Y	D	F
0	19	20	0	0
1	20	20	0	48
2	20	19	0	96
3	19	19	0	144

FROM FOUR ▨ PIXELS, PIXEL VALUES AT (F,D)=(0,0) IN POLAR COORDINATE IMAGE ARE DETERMINED

Fig. 23



XY COORDINATE→ r θ COORDINATE CONVERSION TABLE

No.	X	Y	D	F
0	19	20	0	0
1	20	20	0	48
2	20	19	0	96
3	19	19	0	144

FROM FOUR ▨ PIXELS, PIXEL VALUES AT (F,D)=(0,0) IN POLAR COORDINATE IMAGE ARE DETERMINED

Fig. 24

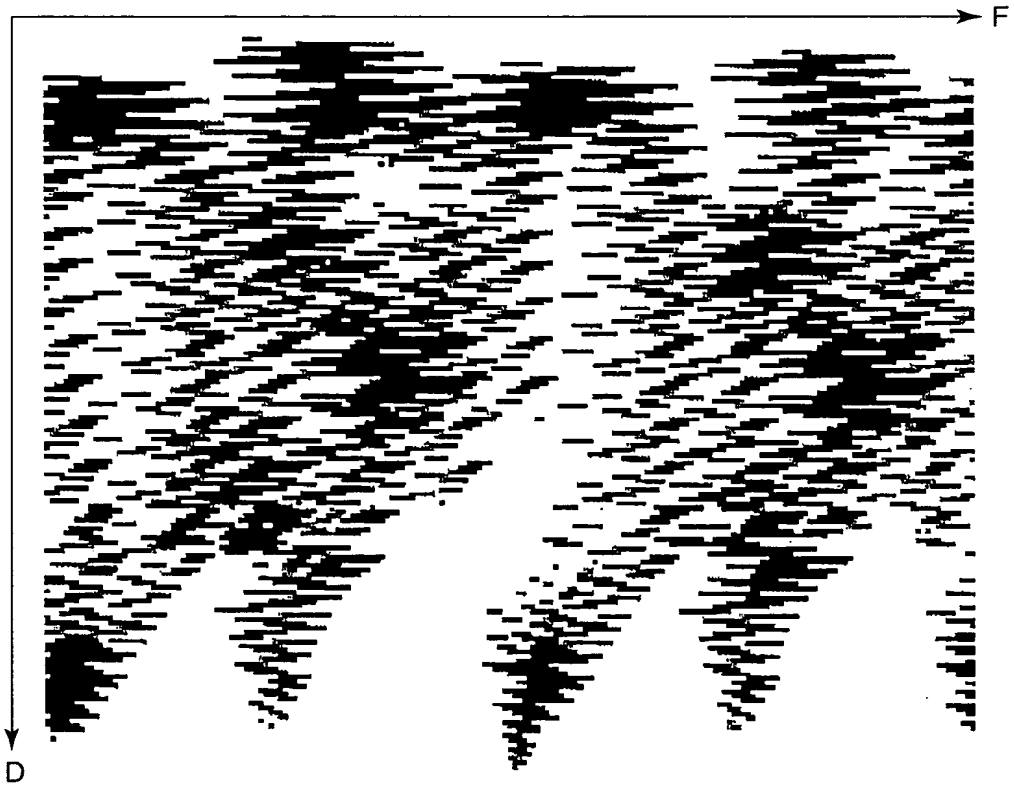


Fig. 25

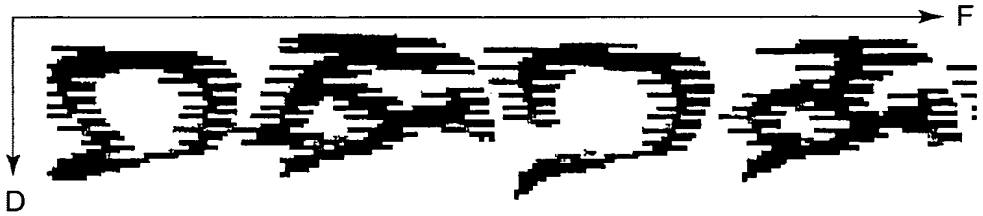
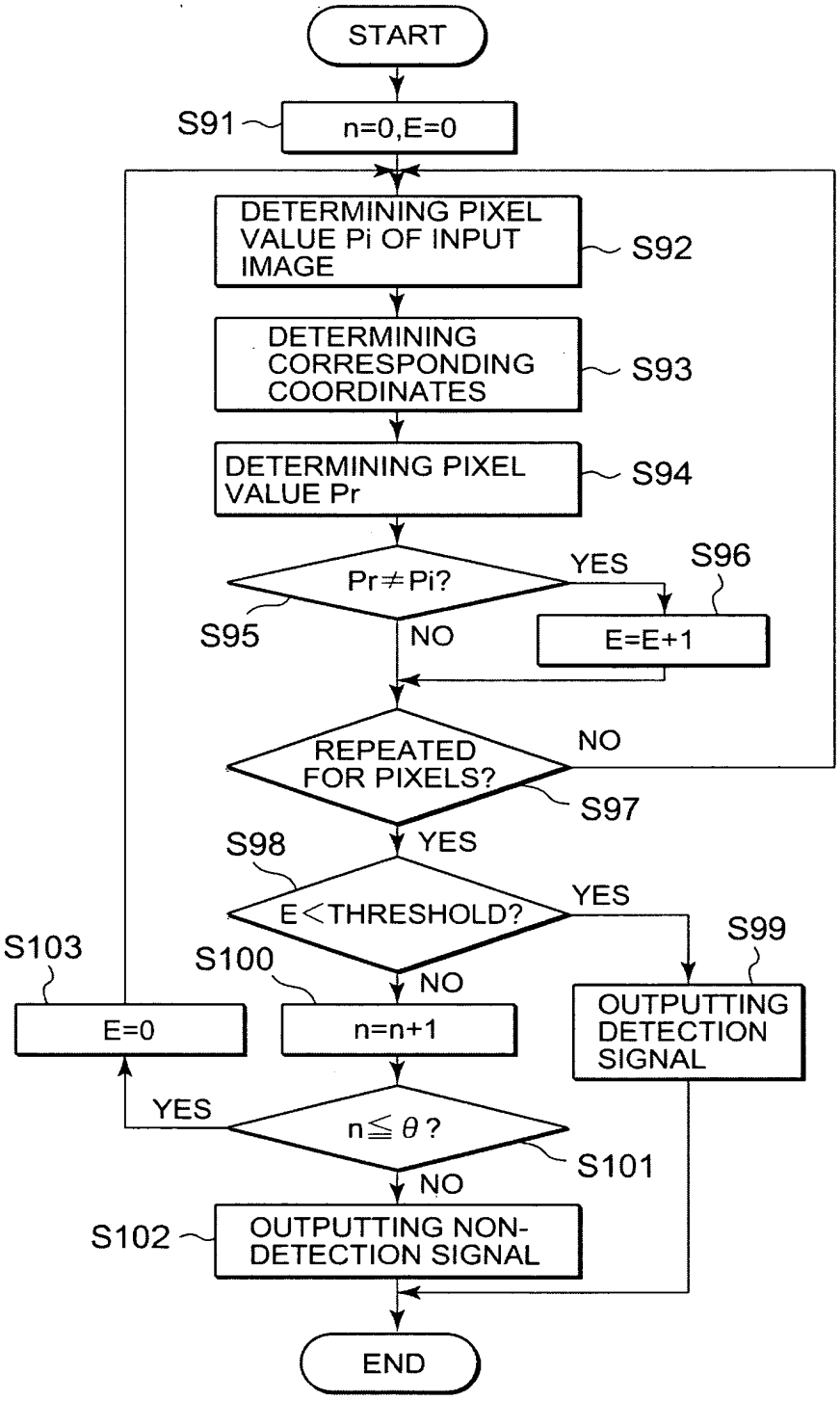


Fig. 26


START
S91
n=0,E=0
DETERMINING PIXEL VALUE Pi OF INPUT IMAGE
S92
DETERMINING CORRESPONDING COORDINATES
S93
DETERMINING PIXEL VALUE Pr
S94
Pr≠Pi?
YES
S96
S95
NO
E=E+1
REPEATED FOR PIXELS?
NO
S97
YES
S98
E<THRESHOLD?
YES
S99
S103
S100
NO
E=0
n=n+1
OUTPUTTING DETECTION SIGNAL
YES
n≦θ?
S101
NO
S102
OUTPUTTING NON-DETECTION SIGNAL
END

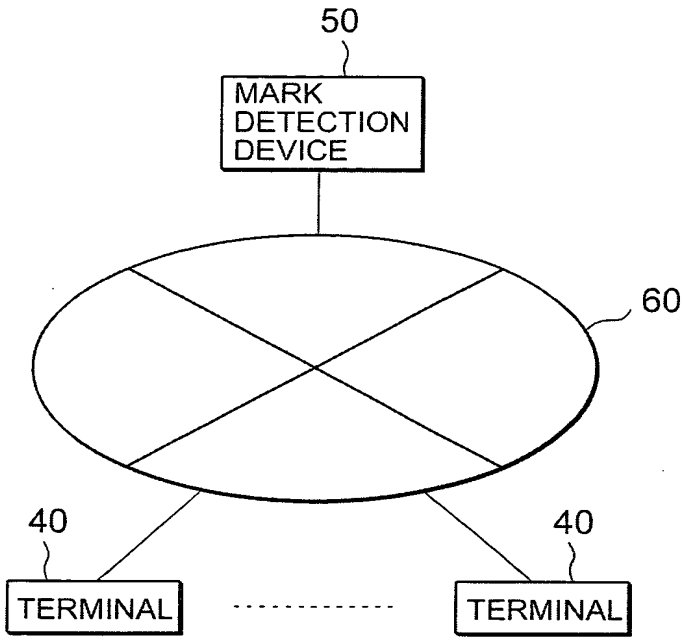



Fig. 27